Morphological Constraints in Children’s Spoken Language Comprehension: A visual world study of plurals inside compounds in English

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ABSTRACT

Many previous studies have shown that the human language processor is capable of rapidly integrating information from different sources during reading or listening. Yet, little is known about how this ability develops from child to adulthood. To gain insight into how children (in comparison to adults) handle different kinds of linguistic information during on-line language comprehension, the current study investigates a well-known morphological phenomenon that is subject to both structural and semantic constraints, the plurals-in-compounds effect, i.e. the dislike of plural (specifically regular plural) modifiers inside compounds (e.g. rats eater). We examined 96 seven-to-twelve-year-old children and a control group of 32 adults measuring their eye-gaze changes in response to compound-internal plural and singular forms. Our results indicate that children rely more upon structural properties of language (in the present case, morphological cues) early in development and that the ability to efficiently integrate information from multiple sources takes time for children to reach adult-like levels.

KEYWORDS: Developmental morphology; compounding; visual world paradigm; eye movements; morphological processing
1. Introduction

Successful and efficient language processing requires the ability to utilize multiple cues from different sources (e.g. grammar, lexicon, semantics, pragmatics) within short time intervals. Most previous experimental research has focused on the nature of the mature language processing system demonstrating that adults are indeed capable of rapidly and efficiently integrating information from different sources during language processing (e.g. Spivey et al., 2002; Tanenhaus & Trueswell, 2005). Children’s language processing has only been examined in a small number of studies using online techniques (see Clahsen, 2008 for review), and the question of how the human language processor develops from child to adulthood remains largely unanswered. Against this background, the current study investigates constraints on modifiers inside compounds as a window to the information sources children (in comparison to adults) employ during language processing.

Compounds in English offer a strong contrast between singulars (which are preferred), irregular plurals (which are less acceptable), and regular plurals (which are even worse) as compound-internal modifiers; compare, for example owl/ox breeder vs. owls/oxen breeder. The distribution of plurals inside compounds has been derived from the interplay of different kinds of constraints. The preference for irregular over regular plural non-heads (e.g. mice eater vs. rats eater) has been attributed to a morphological constraint that bans outputs of regular inflectional processes (e.g. –s plurals in English) to be entered as non-heads into lexical compounds (e.g. Berent & Pinker, 2007). The preference of singular over plural non-heads inside compounds (e.g. rat/mouse eater vs. rats/mice eater) has been attributed to a semantic constraint against compound-internal modifiers that specify multiple entities (Haskell, MacDonald, & Seidenberg, 2003). With these properties, the so-called ‘plurals-in-
The plurals-in-compounds effect has also featured prominently in debates about the role of innate constraints on child language acquisition. Starting with Gordon (1985), several studies have shown that three-to-five-year-old children allow irregular plurals inside compounds but consistently omit correct regular and overregularized –s plurals from inside compounds. Thus, children may sometimes produce incorrect plural forms such as *mouses*, but never as a non-head element of a compound (e.g. *mouses-eater* or *rats-eater*). Gordon (1985) argued that children are sensitive to the ban against regular plurals inside compounds even though these contrasts are not available from adult speech. Pinker (1999: 208) took this finding as a ‘…product of the innately specified architecture of the(ir) language system…’. However, the nature of the plurals-in-compounds effect in children is controversial. Ramscar and Dye (2010) have argued that these claims are unnecessary and that the distribution of plurals inside compounds can indeed be learned from the input. The current study complements this controversy with novel findings from an investigation of the timecourse of the compounding constraints during spoken language comprehension. We employed the visual world paradigm in which participants’ looks to visual displays were monitored while they were listening to compounds with regular and irregular plural as well as singular modifiers. Our findings show that the different
compound-internal modifiers affect participants’ looking-while-listening performance and that there are developmental changes from child to adult in this domain.

2. Constraints on inflections inside compounds in English

The constraints on modifiers inside compounds have been examined in a number of previous offline rating and production studies. Results from acceptability judgment tasks (Haskell et al. 2003; Cunnings & Clahsen, 2007) have shown that compounds containing singular nouns as non-heads are preferred over plural forms inside compounds. This contrast has been derived from the semantics of compounds (Haskell et al. 2003; Berent & Pinker, 2007). Typically, the non-head of a compound refers to a kind, not an individual or its properties. A mouse-eater eats mice in general, not a particular type or number of mouse. A handgun refers to a particular kind of gun and may still be applied with one or two hands. In English, a singular noun form is identical to a bare nominal stem and is therefore more acceptable inside a compound than a plural form, which is explicitly marked for NUMBER. An additional contrast is between regular and irregular plurals as non-heads of lexical compounds, e.g. rats eater vs. mice eater. Regular plurals inside compounds are judged considerably worse than irregular plurals (e.g. Haskell et al. 2003; Cunnings & Clahsen, 2007), and in elicited production, young children, adolescents, and adult native speakers include significantly more irregular plurals than regular ones inside compounds (e.g. Gordon, 1985; Murphy, 2000; van der Lely & Christian, 2000). The source of this contrast is controversial. Several linguists have argued that this phenomenon is grammatical in nature, reflecting a contrast between lexically stored and grammatically computed forms. Kiparsky (1982) argued that regular inflection is strictly ordered after other morphological processes such as irregular inflection,
derivation, and compounding so that regular inflectional affixes are effectively prevented from appearing inside compounds; see also Di Sciullo and Williams (1987), Borer (1988), and Wiese (1996) for related accounts.

As an alternative to this morphological constraint, Haskell et al. (2003) proposed that the surface-form properties of regular plural nouns are responsible for their ban inside compounds, specifically a dislike of modifiers with sibilant-final codas; see also Seidenberg, MacDonald and Haskell (2007) and Ramscar and Dye (2010). Another non-morphological attempt (Buck-Gengler, Menn & Healey, 2004) to explain this phenomenon claims that regular plural non-heads are less likely to be produced inside compounds than irregular ones because the surface forms of the former overlap more with their corresponding singular forms (e.g. rats vs. rat) than the surface forms of the latter (e.g. mice vs. mouse). Consequently, the preferred forms for modifiers inside compounds, namely singular forms, are more easily accessible from regular than from irregular plurals.

There are, however, problems with these non-morphological accounts. The supposed dislike of compound modifiers with sibilant-final codas has been disconfirmed by results from acceptability judgment tasks (Berent & Pinker, 2007; Cunnings & Clahsen, 2007) showing that compounds such as fox chaser or news reader are rated as being fully acceptable by native speakers of English, and that mice eater and geese eater are rated better than rats eater and ducks eater, even though all of these compounds contain modifiers with s/z final codas. The problem with Buck-Gengler et al.’s (2004) proposal is that if accessibility to the preferred singular form was the decisive factor, then it would be mysterious why in acceptability judgment tasks regular plural non-heads (from which the singular is supposed to be easily accessible) are dispreferred over irregular ones in compounds.
For these reasons, we do not think that any of the proposed non-morphological accounts of the plurals-in-compounds effect is viable and instead maintain that the dislike of regular plurals inside compounds is due to a morphological constraint that restricts concatenative regular inflection from feeding further word formation processes. This constraint together with the semantic constraint mentioned above accounts for the three-way pattern of acceptability ratings reported in a number of studies for adult native speakers of English (e.g. Haskell et al., 2003; Berent & Pinker, 2007; Cunnings & Clahsen, 2007). Compounds containing uninflected modifiers (rat eater) do not violate any of these constraints and are fully acceptable. Compounds containing irregular plurals violate the semantic but not the morphological constraint, and are marginally acceptable (mice eater). Compounds containing regular plurals violate both constraints and are even worse than the other types of non-head (rats eater).

The presence or absence of regular plurals inside compounds also influences English speakers’ interpretations of structurally ambiguous compounds. A novel adjective-noun-noun compound such as red rat eater can be interpreted in two ways; a ‘non-recursive’ interpretation ([red [rat eater]]) in which the rat eater is red and the color of what is being eaten is unspecified, and a ‘recursive’ interpretation ([[red rat] eater]) where the color of the eater is unspecified and it is the rats that are red. Both adult and child English speakers have been shown to prefer the non-recursive interpretation for compounds containing singulars (e.g. red rat eater), whereas for compounds with regular plural non-heads (e.g. red rats eater) there was a strong preference for the recursive reading. This contrast has been attributed to the morphological constraint against –s plurals inside compounds, which rules out the
non-recursive interpretation but permits the recursive one (Alegre & Gordon, 1996; Clahsen & Almazan, 2001).

This interpretation has recently been criticized by Ramscar and Dye (2010). They pointed out a methodological problem in these experiments resulting from the fact that participants were only presented with *multiple* objects depicting the non-head and *single* objects for the head noun, for example, in the case of red rats eater, with multiple rats and a single eater. Ramscar and Dye (2010) argued that this may have biased participants towards the recursive interpretation in the plural condition. To address this and other concerns, Ramscar and Dye (2010) performed four offline experiments with a similar design as Alegre and Gordon’s (1996) original study, but with a number of modifications. They included picture stimuli with single objects for the non-head element and compounds with irregular plural non-heads (*mice eater*), rather than just regular and singular ones. They also manipulated the semantic fit between the adjective and the non-head/head of the compound, comparing, for example, items such as *identical twins projects to controversial twins project*, with the former semantically biased towards a recursive and the latter towards a non-recursive compound interpretation. Results from groups of adults and 3-to-5-year-old children revealed a preference for recursive interpretations for compounds with plural (relative to singular) non-heads, but no reliable difference between regular and irregular plural non-heads. Furthermore, children’s and adults’ preferences for recursive vs. non-recursive compound interpretations were found to be affected by the semantic fit between the adjective and non-head/head noun. Ramscar and Dye (2010) conclude that these findings disprove any kind of morphological or grammatical basis of the plurals-in-compounds effect. Instead the modifier interpretation preferences for
compounds are due to ‘conventions’ that are directly learned from the input that exclude both regular and irregular plurals from compounds.

Although Ramscar and Dye (2010) present their own account as ‘…a simple, compelling and economical explanation…’ (p. 37), we remain unconvinced, for a number of reasons. Firstly, they incorrectly assume that a grammatical account of the plurals-in-compounds effect excludes the possibility of other factors influencing the distribution of compound-internal modifiers. The account originally proposed by Gordon (1985) adopts a morphological constraint - independently motivated by linguistic considerations (Kiparsky, 1982 and subsequent work) - according to which concatenative regular inflection should not feed word formation processes. This constraint explains the dislike of –s plurals in lexical compounds of English, but has nothing to say about the distribution of irregular plural or semantically plausible vs. implausible modifiers inside compounds. Thus, Ramscar and Dye’s (2010) observations that singular non-heads are preferred in compounds relative to both regular and irregular plural non-heads, that recursive vs. non-recursive interpretation preferences are affected by semantic fit, and that compound-internal plurals are infrequent in English usage do not prove or disprove the morphological constraint.

The second problem is that Ramscar and Dye (2010) do not offer an explanation for why regular plurals are banned from inside compounds. They note that plurals in compounds are rare in the input, but why regular plurals are consistently and across different studies rated as worse than both singulars and irregular plurals inside compounds is left unexplained (e.g. Haskell et al., 2003; Cunnings & Clahsen, 2007).

While several studies have shown that both children and adults obey the constraints on modifiers inside compounds offline, the question of how the compounding constraints affect the timecourse of language processing has only been
investigated in two previous studies examining adults only. Buck-Gengler et al. (2004) recorded naming latencies of elicited compounds. However, this type of reaction time measure does not provide a high enough temporal resolution to gain insight into the moment-to-moment processes involved in real-time language comprehension. Cunnings and Clahsen (2007) recorded participants’ eye-movements as they read sentences with compounds containing singular, irregular plural and regular plural non-heads. Violations of the –s plural constraint affected eye-fixation durations during early stages of processing, indexed by increased first-fixation and gaze durations, whereas effects of the semantic constraint were in comparison delayed, reflected in increased rereading and total reading times. While the recording of eye-movements during reading provides a rich source of information regarding the timecourse effects of the compounding constraints, this technique is not suitable for young children who have not acquired adequate reading ability to deal comfortably with written text.

3. The present study

To investigate how the compounding constraints affect the timecourse of processing in both adult native speakers and child acquirers of English, we employed the visual world paradigm in which participants view a visual display whilst listening to experimentally manipulated sentences. Inferences can be made about language processing by analyzing the pattern of eye-movements across the visual display over time as the sentence unfolds. Researchers have used this paradigm to compare the timecourse of processing for a number of linguistic phenomena in adults and children (Fernald, Zangl, Portillo & Marchman, 2008; Trueswell, 2008; Clackson, Felser & Clahsen, 2011).
The current study used structurally ambiguous compounds such as *red rat(s) eater* as a window into how the compounding constraints affect participants’ spoken language comprehension. These compounds allow for either a recursive interpretation (i.e., [\text{NP}[\text{red rats} \text{ eater}]]) in which the first noun is taken to be modified by the adjective, or a non-recursive interpretation ([\text{red} \text{N}[\text{rats eater}]) in which the adjective is interpreted to modify the second noun. The dependent measure we used to determine online performance was changes of looks to pairs of pictures presented during listening, one showing the victims in the stated color, e.g. a picture of red rats, and the other showing the predator in the stated color, e.g. a red monster.

With this design we can assess competing accounts of the plurals-in-compounds effect using a time-sensitive measure of spoken language comprehension. If the *morphological constraint* affects online performance, the recognition of a regular plural non-head (relative to an irregular one) should lead to an increase of looks to the picture depicting the recursive compound interpretation. In addition, sensitivity to the *semantic constraint* should be reflected in increases of looks to the recursive picture for compounds containing plural (as opposed to singular) non-heads. According to Ramscar and Dye’s (2010) ‘learning’ account, by contrast, regular and irregular plural non-heads inside compounds should yield *parallel* increases of looks to the recursive picture, due to the fact that both regular and irregular plural non-heads inside compounds are absent from a child’s input.

With respect to the relative timing of the compounding constraints, there is evidence from an eye-movement study (Cunnings & Clahsen, 2007) that adult native speakers of English apply the morphological constraint earlier than the semantic constraint during reading. We expect to replicate this finding for spoken language comprehension. Regarding developmental changes from child to adulthood, previous
findings from offline studies lead us to expect that seven-to-twelve-year-old children’s final interpretations of the kinds of compounds tested are similar to adults. On the other hand, evidence from studies investigating ambiguity resolution during sentence comprehension suggests that school-age children are less efficient than adults at rapidly accessing and integrating multiple sources of information for processing (e.g. Trueswell, 2008; Felser & Clahsen, 2009). Instead, children were found to rely more on structural information and less on semantic information for ambiguity resolution (e.g. Traxler, 2002; Felser, Marinis & Clahsen, 2003). Given these findings, we expect children to show a greater/earlier sensitivity to the morphological constraint (which is structurally driven) compared to the semantic constraint.

4. Methods

The purpose of this experiment was to examine how the compounding constraints affect the timecourse of processing during listening. Participants listened to a series of short two-sentence paragraphs containing compounds with different kinds of modifiers whilst their eye-movements to visual displays containing pictures of potential referents were monitored.

4.1 Participants

Ninety-six school-age children between the ages of 7;7 and 12;9 were recruited from two state schools and one private school in the Essex (UK) area. Six of these children had to be excluded from any further analysis, as they were not concentrating on the picture stimuli resulting in more than 50% of data loss during tracking for these children. The remaining 90 children were assigned to three age bands, 30 children
with a mean age of 8.16 (range: 7;7-8;11), 28 children with a mean age of 10.18
(range: 9;3-10;11), and 32 children with a mean age of 11.51 (range: 11;0-12;9). All
had acquired British English as their native language from birth and were identified
by their teachers as having no language or learning difficulties, and to be performing
within normal parameters for their age. Parental consent was obtained prior to their
testing. The experiment was also administered to a control group of 32 adult native
speakers of British English recruited from among the students and staff of the
University of Essex, who were paid a small fee for their participation (mean age:
26.32, range: 18;7-62;2). Both the child and the adult groups contained an equal
number of male and female participants (n=16 women, n= 45 girls).

4.2 Materials
The critical materials were similar to those of Alegre and Gordon’s (1996) offline
task, but were adapted to the requirements of a visual world experiment. Moreover,
the data set for the current study was expanded to include irregular plural forms. In
this way, the potential impact of the –s plural constraint can be evaluated, by
comparing performance on compounds with regular and irregular plural non-heads,
irrespective of the preference for singular (as opposed to plural) modifiers inside
compounds. The materials consisted of visual displays separated in the center by a (3-
point) line from top to bottom and spoken pairs of sentences.

The visual displays consisted of pairs of cartoon-like line drawings such as the
one in Figure 1 produced by a professional cartoonist. The pictures were an exact
mirror image, except that the colors were reversed. The visual display for blue girl(s)
kisser / blue woman (women) kisser, for example, consisted of two pictures A and B
of a large creature kissing a number of women/girls. Picture A (on the left of the
display) refers to the recursive compound interpretation, and presents a large yellow creature (the *kisser*) and blue females, while Picture B (on the right of the display) is identical, except that it refers to the non-recursive compound interpretation, with the *kisser* being blue and the females being yellow. The positioning of the two types of picture A and B in the visual displays was counterbalanced across items, such that each picture appeared on the left in half of the trials and on the right in the other half.

*Figure 1: Example of visual display*

<table>
<thead>
<tr>
<th>Picture A</th>
<th>Picture B</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Picture A" /></td>
<td><img src="image2" alt="Picture B" /></td>
</tr>
</tbody>
</table>

The audio stimuli consisted of one of four versions of a sentence pair such as

‘*Here is the blue girl(s)/woman(women) kisser. Point to the blue girl(s)/woman(women) kisser.*’ Sound files of all trials were recorded by a female native British English speaker, who was naïve with respect to the purpose of the study and who did not take part in the data collection. Splicing was applied so as to reduce as far as possible potential effects of prosody. The color adjectives and non-head elements, e.g. *blue* and *kisser*, were spliced to ensure that these words were identical
in the four conditions. The non-head nouns (e.g. girl(s)/woman(women)) were recorded separately and then inserted. The head nouns were between 406 and 615ms long (mean: 500ms), and the length of the pauses between the three words was identical across the four conditions.

The materials were constructed specifically for use with children, with nouns familiar to school-age children. For the construction of the critical items, 8 nouns that take irregular plural inflections were matched for frequency, length and meaning with 8 nouns that take the regular plural (e.g. duck/ducks vs. goose/geese) plus 16 corresponding singular forms. All non-heads were similar in length, in terms of number of phonemes and mean durations (in ms.), as well as in terms of frequency; see Table 1. Frequency counts were based on the spoken language samples of the CELEX Lexical Database (Baayen, Piepenbrock & van Rijn 1993). Following Cunnings and Clahsen (2007), word-form frequencies for the irregular plural items were matched to the stem/lemma frequencies of the regular plural items and singulars. One-way ANOVAs revealed no differences between regular, irregular, and singular non-heads for any of the matched variables shown in Table 1 (all p values > .1). Non-heads did not include compounds or derived words. Each non-head noun appeared with two deverbal head nouns yielding a total of 32 compounds with plural non-heads (16 regular, 16 irregular ones) plus 32 compounds with the corresponding singular non-heads (duck/goose feeder/catcher, beetle/louse eater/catcher, rat/mouse catcher/eater, baby/child kisser/tickler, girl/woman kisser/hugger, boy/man biter/chaser, eye/tooth painter/collector, hand/foot tickler/nibbler). Note that all non-heads were simplex nouns and did not include compounds or derived word forms. Furthermore, to avoid assimilation confounds, sibilant-initial head nouns and non-head nouns with voice-change plural forms, such as wolf > wolves, were not used.
Table 1: Mean frequency and mean length of non-head nouns

<table>
<thead>
<tr>
<th></th>
<th>Regular plural</th>
<th>Irregular plural</th>
<th>Singulars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency/million</td>
<td>119.00</td>
<td>167.75</td>
<td>121.25</td>
</tr>
<tr>
<td>Number of phonemes</td>
<td>4.13</td>
<td>4.00</td>
<td>3.69</td>
</tr>
<tr>
<td>Durations (in ms.)</td>
<td>396.13</td>
<td>403.44</td>
<td>379.66</td>
</tr>
</tbody>
</table>

*Source: CELEX (spoken); stem/lemma frequency for regulars, word-form frequency for irregulars.

In addition to the critical trials, the linguistic materials included 32 auditory filler items containing the same format of sentence pairs (*Here is ... Point to...*) as the critical items but a range of different kinds of complex noun phrase (NP) with modifier attachment ambiguities. Half of the filler trials consisted of compounds with gerunds as non-heads and simplex nouns as head nouns (e.g. red building hugging monster), 8 of which with the same distribution of color as the critical items and 8 paired with visual displays containing differently colored objects (unlike the critical items). There were also 8 filler items with pluralia tantum non-heads half of which with a non-head-final –s and half without (e.g. red glasses cleaner, vs. blue trouser mender). Finally, we included 8 items with a coordinated NP plus a PP modifier yielding a global modifier ambiguity (e.g. the girl and the rabbit in the boat).

The experimental items were distributed evenly across four lists, such that each list had the same number of tokens from each condition. The same set of filler trials was used with each list. All trials were presented in a pseudo-randomized order such
that no more than two experimental trials occurred consecutively. The four lists were then reversed to create eight lists altogether.

4.3 Procedure
Participants sat in a chair facing a 22” monitor 80cm from the participants’ eyes on which the visual displays were projected and listened to the auditory stimuli containing the critical compounds through headphones or via speakers. The task assigned to the participants was to respond to the aurally presented command (Point to…) by pointing with their arms either to the right or to the left of the monitor. Prior to the eye-movement experiment, the children were asked to name the colors used in the main experiment. The adults were pre-screened via a questionnaire before participating in the experiment to ensure they were not color-blind. All of the children performed the color identification task without errors. A vocabulary pre-test was also administered to the children on all critical non-head nouns. If any items were unfamiliar to a participant, these would be trained by the investigator until correct suppliance was obtained in three consecutive attempts. Additionally, the children completed the Competing Language Processing Task (CLPT, Gaulin & Campbell, 1994) in order to ensure that their verbal working memory was within the normal range. The CLPT is an adaptation of Daneman & Carpenter’s (1980) reading span task for children and requires participants to listen to sets of one to six sentences consisting of three words each, to provide a truth-value judgment for each sentence, and to recall the last word of each of the sentences at the end of each set. All children performed as expected for their age range in both components of the task scoring an average of 98% on the true/false statements and 66% on the final word recall of the statements. Instructions for the main experiment were then read out to participants.
Adults were told that the experiment was originally designed for children. All participants were told that the pictures involved monsters, aliens and an imaginary world, where even the humans would have strange colors, and that these people and creatures might be involved in unusual activities. Participants were also asked to listen to both sentences before deciding which picture to point to, and were warned that in some cases characters mentioned in the two sentences could refer to different pictures, as was the case for certain filler items (e.g. *Here is the red building hugging monster. Point to the blue building hugging monster*). Finally, participants were asked to keep their head relatively still and only move their eyes around the screen for the duration of the eye-movement experiment. Following these instructions, a nine-point calibration was run during which all participants followed a cartoon character around the screen. If necessary, the calibration was repeated. Once the calibration was complete, six practice trials were presented, which served to further familiarize participants with the visual displays and the auditory stimuli. After the practice session participants were given the opportunity to ask questions before commencing the eye-movement experiment. Participants were also told that the investigator would remain in the room sitting behind them, to record which picture they pointed to. During the main experiment, the researcher monitored the participants’ attention, gently reminding them to keep looking at the screen if their attention wandered.

Children were tested in a dedicated room at their school; adults in the visual world laboratory at the University of Essex. A consent form was signed and a short personal information questionnaire filled in by the adult participants or the children’s guardians. During the experiment, participants’ eye-movements were recorded at a sample rate of 60Hz using a remote eye-tracking device (SMI’s RED 250 system,
iViewX v.2.7) which was placed below the monitor. Each experimental session lasted 20 minutes for the adults and 45 minutes for the children.

4.4 Data coding and Analysis

The eye movement data from iViewX were converted into text files and read into BeGaze v.3.0 (SMI). Each of the two pictures on one side of the screen indicating either a recursive or a non-recursive interpretation represented one area of interest. Off-screen looks and blinks (which accounted for 3.42% of the total dataset) were treated as missing data. The remaining data from BeGaze were then transformed, cut into time windows using Perl v.5 scripts, and entered into statistical analyses. Mixed-effects logistic regression models were applied using the ‘R’ software package, version 2.15.1 (R Development Core Team, 2012) and the R package lme4 (Bates & Sarkar, 2007). Analyses were carried out on the raw data with no aggregation over time, conditions, participants or items (Baayen, Davidson & Bates, 2008) for a time window of 0 to 1500ms starting at 100ms after the onset of the head noun of the compound in the first sentence, e.g. *kisser* in the case of ‘*Here is the blue woman kisser…*’. During this time window participants were listening to the head noun, which had a mean duration of 500ms, plus the pause between the first and the second sentence, which had a duration of 1,500ms. The binary dependent variable encoded whether the picture depicting the recursive interpretation of the compound was, or was not, fixated for each of the 17ms frames. Models were fit to test for subject and item random intercepts and random slopes for each fixed factor. These were Condition (Singular, Irregular Plural, Regular Plural), Group (Adults and Children), Time (Linear and Quadratic) and Age. The fixed factor ‘Condition’ was examined in two ways, firstly by comparing proportions of looks for compounds containing
regular versus irregular plural non-heads, ‘Condition (Reg vs. Irr)’, and secondly by comparing proportions of looks for compounds containing plural (regular and irregular ones combined) to those with singular non-heads, ‘Condition (Sing vs. Plur)’. The former comparison specifically assesses the potential impact of the morphological constraint against regular plural non-heads and the latter the semantic constraint, i.e., the potential preference of singular (as opposed to plural) modifiers in compounds. Regarding the predictor ‘Time’, both first and second order polynomial time (Linear, Quadratic) were examined (Mirman, Dixon, & Magnuson, 2008; Trueswell & Papafragou, 2010), to capture potential nonlinear changes of gaze over time. Of the predictors only those that led to a significant improvement in the fit of the model were retained, such that the best fit model was achieved. Models were first fit to the full data set (from both adults and children); afterwards interaction terms were further explored by analyzing data from each group separately.

5. Results

Before examining the online eye-movement data, consider first participants’ final interpretations of the compounds as revealed by their pointing responses; see Table 2.

Table 2: Mean percentages of pointing responses to the recursive picture

<table>
<thead>
<tr>
<th></th>
<th>Regular plurals</th>
<th>Irregular plurals</th>
<th>Plurals</th>
<th>Singulars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td>55.47</td>
<td>53.13</td>
<td>54.30</td>
<td>45.88</td>
</tr>
<tr>
<td>Children</td>
<td>54.60</td>
<td>55.03</td>
<td>54.81</td>
<td>45.69</td>
</tr>
</tbody>
</table>
Recall that participants were given two choices for their pointing responses (see Figure 1 above), a picture depicting the recursive (Picture A) and another one depicting the non-recursive compound interpretation (Picture B). Table 2 presents mean percentages of pointing responses to the picture depicting the recursive interpretation. These data show significantly more recursive picture choices for compounds with plural non-heads, both regular and irregular ones, than for those with singular non-heads in both participant groups (adults: $t=2.39$, children: $t=4.21$). On the other hand, the more subtle contrast between regular and irregular plural non-heads did not yield reliable differences in participants' ultimate compound interpretations (adults: $t=0.46$, children: $t=0.04$). The same pattern of results was found in Ramscar and Dye's (2010) experiment 1, an offline interpretation rating task with similar materials to the ones tested here.

To provide an overview of the eye-movement data, the results will first be presented in the form of descriptive graphs followed by statistical analyses. The eye-movement data are shown in Figure 2 for adults and Figure 3 for children. Figures 2 and 3 present proportions of fixations to the recursive picture over time, after the onset of a compound’s head noun with either a regular plural, irregular plural, or singular non-head. For ease of exposition, the graphs for the adults and the children are shown in two figures each. Figures 2A and 3A present the data for compounds with regular compared to irregular plural non-heads, and Figures 2B and 3B for compounds with plural (regular and irregular ones combined) non-heads compared to those with singular ones. The x-axis displays the time in milliseconds starting at 100ms after the onset of the head noun for a time window of 1,500ms during which participants were listening to the head noun of the compound in the first sentence of each trial plus the
pause between the two sentences. The y-axis illustrates the proportion of fixations (subject means) to the recursive picture, i.e. the number of times a participant looked at the recursive picture in a given time frame of 17ms as a proportion of the total number of fixations of one of the two pictures. Note that it takes about 200ms to program an eye-movement (Rayner, Slowiaczek, Clifton, & Bertera, 1983) and that only changes in proportions of fixations after this time can be attributed to participants’ processing of the critical stimulus.

**Figure 2:** Adults’ proportions of looks to the recursive picture

<table>
<thead>
<tr>
<th>Regular vs. Irregular</th>
<th>B. Plural vs. Singular</th>
</tr>
</thead>
</table>

![Graph](image1)

**Figure 3:** Children’s proportions of looks to the recursive picture

<table>
<thead>
<tr>
<th>A. Regular vs. Irregular</th>
<th>B. Plural vs. Singular</th>
</tr>
</thead>
</table>

![Graph](image2)
Concerning the adult group, Figure 2A shows an early contrast between compounds with regular and irregular plural non-heads, with the former yielding an increase of looks to the recursive picture between 200 and 500ms after the onset of head noun. In addition, Figure 2B shows an increase of adults’ looks to the recursive picture for compounds with plural (compared to singular) non-heads starting around 700ms and peaking at 1,000ms after the onset of the head noun. The child data in Figure 3A displays a gradual long-lasting increase of looks to the recursive picture peaking around 1,200ms after the onset of the head noun for compounds with regular plural non-heads (relative to irregular ones). In contrast to adults, however, head nouns of compounds with plural compared to singular non-heads did not prompt any recognizable changes of children’s looks; see Figure 3B.

As mentioned above, we used mixed-effects logistic regression models to analyze the eye-movement data statistically. The results from the best model fit to the full data set from both the adult and the child groups are shown in Table 3, which presents all statistically significant results; there were no other reliable main effects or interactions. For both comparisons (‘Sing vs. Plur’ and ‘Reg vs. Irr’), Table 3 shows significant interactions with Time, both ‘Linear’ and ‘Quadratic’, and ‘Group’. These interactions indicate child/adult differences with respect to changes of looks over time for both compounds with regular (relative to irregular) plural non-heads and for compounds with plural (relative to singular) non-heads. To further examine these interactions, separate models were fitted to the data for each of the two participant groups.
Table 3: Fixed effects regression model fit to both the child and the adult data

<table>
<thead>
<tr>
<th>Fixed effects</th>
<th>Estimate</th>
<th>St. Error</th>
<th>z Value</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-0.319</td>
<td>0.162</td>
<td>-1.969</td>
<td>.049 *</td>
</tr>
<tr>
<td>Linear x Quadratic</td>
<td>-0.531</td>
<td>0.112</td>
<td>-4.751</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Linear x Condition (Sing vs. Plur)</td>
<td>-0.601</td>
<td>0.298</td>
<td>-2.018</td>
<td>.044 *</td>
</tr>
<tr>
<td>Quadratic x Condition (Reg vs. Irr)</td>
<td>-1.965</td>
<td>0.707</td>
<td>-2.781</td>
<td>.005 *</td>
</tr>
<tr>
<td>Quadratic x Condition (Sing vs. Plur)</td>
<td>1.078</td>
<td>0.481</td>
<td>2.242</td>
<td>.025 *</td>
</tr>
<tr>
<td>Quadratic x Group</td>
<td>2.568</td>
<td>0.576</td>
<td>4.459</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Linear x Quadratic x Condition (Reg vs. Irr)</td>
<td>1.130</td>
<td>0.304</td>
<td>3.722</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Linear x Quadratic x Condition (Sing vs. Plur)</td>
<td>-0.454</td>
<td>0.208</td>
<td>-2.188</td>
<td>.029 *</td>
</tr>
<tr>
<td>Linear x Quadratic x Group</td>
<td>-1.419</td>
<td>0.223</td>
<td>-6.349</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Quadratic x Condition (Reg vs. Irr) x Group</td>
<td>5.172</td>
<td>1.413</td>
<td>3.659</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Quadratic x Condition (Sing vs. Plur) x Group</td>
<td>3.163</td>
<td>0.961</td>
<td>3.292</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Linear x Condition (Reg vs. Irr) x Group</td>
<td>-2.058</td>
<td>0.867</td>
<td>-2.374</td>
<td>.018 *</td>
</tr>
<tr>
<td>Linear x Condition (Sing vs. Plur) x Group</td>
<td>1.170</td>
<td>0.595</td>
<td>1.965</td>
<td>.049 *</td>
</tr>
<tr>
<td>Linear x Quadratic x Cond. (Reg vs. Irr) x Group</td>
<td>-3.028</td>
<td>0.607</td>
<td>-4.988</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Linear x Quadratic x Cond. (Sing vs. Plur) x Group</td>
<td>-1.552</td>
<td>0.415</td>
<td>-3.737</td>
<td>&lt;.001 *</td>
</tr>
</tbody>
</table>

Formula in R: DepVar ~ Linear * Quadratic * Condition * Group + (1 + Linear + Quadratic + Condition + Group + Quadratic :Condition + Quadratic :Group | Part) + (1 + Linear + Quadratic + Condition + Group | Item)

The statistically significant results from the best model fit to the adult data are shown in Table 4; there were no other main effects or interactions. Firstly, for ‘Reg vs. Irr’, Table 4 shows a main effect of Condition reflecting the preference for the recursive picture in the regular relative to the irregular condition. Secondly, for ‘Sing vs. Plur’, Table 4 shows reliable interactions with both Linear Time and Quadratic Time, indicating that adults’ gaze was subject to different changes over time for
compounds with plural (relative to singular) non-heads. These differences are visible from Figure 2B in that head nouns of compounds with plural non-heads yielded a late increase of looks (from 700ms to 1,000ms) to the recursive picture whereas for compounds with singular non-heads there was no such increase\(^1\).

Table 4: Fixed effects from regression model fit to the adult data

<table>
<thead>
<tr>
<th>Fixed effects</th>
<th>Estimate</th>
<th>St. Error</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-0.366</td>
<td>0.259</td>
<td>-1.413</td>
<td>.158</td>
</tr>
<tr>
<td>Quadratic</td>
<td>2.134</td>
<td>0.557</td>
<td>3.834</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Condition (Reg vs. Irr)</td>
<td>0.507</td>
<td>0.125</td>
<td>4.068</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Linear x Quadratic</td>
<td>-1.446</td>
<td>0.199</td>
<td>-7.270</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Quadratic x Condition (Sing vs. Plur)</td>
<td>2.900</td>
<td>1.085</td>
<td>-2.674</td>
<td>.007 *</td>
</tr>
<tr>
<td>Linear x Quadratic x Cond. (Sing vs. Plur)</td>
<td>-1.427</td>
<td>0.367</td>
<td>-3.886</td>
<td>&lt;.001 *</td>
</tr>
</tbody>
</table>

Formula in R: DepVar ~ Linear * Quadratic * Condition + (1 + Linear + Quadratic + Linear :Condition + Quadratic :Condition | Part) + (1 + Linear + Quadratic + Linear :Condition + Quadratic :Condition | Item)

The results from the *child data*, i.e. all significant effects and interactions from the best model fit, are shown in Table 5; there were no other main effects or interactions. Note that we also included Age as a (grand-mean centered) continuous

\(^1\) One reviewer pointed out that the effect we obtained for the 'Sing vs. Plur' comparison might possibly be driven by the regular plural non-head items, because these are more strongly banned from inside compounds than irregular plural non-heads. To address this concern, we performed an additional analysis in which only compounds with irregular plural non-heads were compared to those with singular non-heads. This additional analysis yielded exactly the same main effects and interactions as the comparison of 'Sing vs. Plur', i.e. regular and irregular plural non-heads combined relative to singular ones. Thus, the preference for singular (as opposed to plural) modifiers in compounds cannot (only) be attributed to regular plurals.
factor into this model. Table 5 shows that reliable predictors for children’s gaze involved interactions with Time (both Linear and Quadratic), Condition, and Age. Firstly, for ‘Reg vs. Irr’, there were significant interactions with both Time (both ‘Linear’ and ‘Quadratic’) and Age, indicating that the preference for the recursive picture in the regular relative to the irregular condition (visible from Figure 3A) was subject to both changes over time during listening and to age differences. Secondly, for ‘Sing vs. Plur’, Table 5 also shows reliable interactions with both Age and Time (both ‘Linear’ and ‘Quadratic’). These interactions are again indicative of changes of looks over time and of age differences in children’s performance.

<table>
<thead>
<tr>
<th>Fixed effects</th>
<th>Estimate</th>
<th>St. Error</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-0.305</td>
<td>0.158</td>
<td>-1.933</td>
<td>.053</td>
</tr>
<tr>
<td>Age</td>
<td>-0.185</td>
<td>0.076</td>
<td>-2.422</td>
<td>.015 *</td>
</tr>
<tr>
<td>Quadratic x Condition (Reg vs. Irr)</td>
<td>-3.703</td>
<td>0.884</td>
<td>-4.188</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Condition (Sing vs. Plur) x Age</td>
<td>-0.270</td>
<td>0.128</td>
<td>-2.114</td>
<td>.035 *</td>
</tr>
<tr>
<td>Linear x Quadratic x Condition (Reg vs. Irr)</td>
<td>2.315</td>
<td>0.333</td>
<td>6.952</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Linear x Condition (Sing vs. Plur) x Age</td>
<td>1.206</td>
<td>0.430</td>
<td>2.805</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Quadratic x Condition (Reg vs. Irr) x Age</td>
<td>-1.261</td>
<td>0.605</td>
<td>-2.086</td>
<td>.037 *</td>
</tr>
<tr>
<td>Quadratic x Condition (Sing vs. Plur) x Age</td>
<td>-1.457</td>
<td>0.417</td>
<td>-3.494</td>
<td>&lt;.001 *</td>
</tr>
<tr>
<td>Linear x Quadratic x Cond. (Sing vs. Plur) x Age</td>
<td>0.518</td>
<td>0.153</td>
<td>3.398</td>
<td>&lt;.001 *</td>
</tr>
</tbody>
</table>

To inspect the source of these interactions, consider Figures 4 and 5 which plot differences between proportions of fixations for the two conditions against the
of Figures 4 and 5 is represented by 90 children in three age bands, 30 children between 7;7 and 8;11, 28 children between 9;3-10;11, and 32 children between 11;0 and 12;9. The difference scores in Figure 4 were calculated by subtracting ‘Irr’ from ‘Reg’, i.e. the proportions of looks to the recursive picture for regular minus those for irregular plural non-heads. Likewise, the scores in Figure 5 represent proportions of looks to the recursive picture for ‘Sing’ subtracted from ‘Plur’. Scores above 0 indicate more fixations to the recursive picture for ‘Reg’ than for ‘Irr’ in Figure 4 and for ‘Plur’ than for ‘Sing’ in Figure 5. To additionally examine changes of looks over time across the different age groups of children, both Figures 4 and 5 present scores from two time windows. The straight lines depict difference scores for an early time window from 0 to 750ms after the onset of the compounds’ head noun, and the dotted line represent difference scores for a later time window from 750 to 1,500ms.

Figure 4 shows that in the later time window children of all age groups look more to the recursive picture for compounds with regular than with irregular plural non-heads. In the earlier time window, however, this is only the case for the oldest children. Figure 5 shows that in the earlier time window there is no preference of looks to the recursive picture for any age group. In the later time window, by contrast, compounds with plural non-heads attract more looks to the recursive picture than those with singular non-heads for 9-to-10 and 12-to-13-year old children2.

2 The same contrast is seen when compounds with irregular plural non-heads are compared to those with singular non-heads, i.e. a preference for the recursive picture in the irregular plural condition in the late time window for the older, but not the younger children.
Figure 4: Difference between proportions of fixations to the recursive picture for compounds with regular (vs. irregular) plural non-heads in two time windows.

Figure 5: Difference between proportions of fixations to the recursive picture for compounds with plural (vs. singular) non-heads in two time windows.
6. General Discussion

The current study sought to gather new experimental evidence on how different kinds of constraints on modifiers inside compounds influence children’s and adults’ online processing. We found that the two constraints that restrict the occurrence of inflected non-heads inside compounds influence both adults’ and children’s processing. To examine the role of the morphological constraint (against regular –s plurals), we compared compounds with regular to those with irregular plural non-heads. In the adult group, –s plurals inside compounds yielded increased proportions of looks to the recursive picture from early on, i.e. from approximately 200ms after listening to a compound’s head noun onwards. The child data also revealed an increase of looks to the recursive picture for compounds with regular plural non-heads compared to irregular ones, albeit in a later time window for the younger than the older children; see Figure 4. To examine the role of the semantic constraint (against plural modifiers inside compounds), we compared compounds with plural non-heads (regular and irregular ones combined) to those with singular non-heads. For the adult group, this comparison revealed increased proportions of looks to the recursive picture for compounds with plural non-heads (relative to singular ones) during a late time window of 700 to 1,000ms. In the child group, plural modifiers inside compounds also elicited a late increase of looks to the recursive picture, in the 750 to 1,500ms time window, yet only for two subgroups of older children. Taken together, these findings suggest that the morphological constraint is available to children of all ages tested, whereas the semantic constraint influences later stages of processing and emerges at a later age.

In the following, we discuss the results of the current study with respect to three issues, firstly, the controversy surrounding the nature of the compounding constraints,
secondly the timing of structural and non-structural information during language processing, and thirdly, the observed developmental changes from child to adulthood.

6.1 The morphological constraint: An artifact?

The results from the current study show that for both mature and child native speakers of English, regular plural modifiers promote recursive compound interpretations, replicating results from previous offline studies with similar materials (Alegre & Gordon, 1996; Clahsen & Almazan, 2001; Ramscar & Dye, 2010). While these findings demonstrate that –\textit{s} plural non-heads are dispreferred inside compounds, the source of this effect is controversial. One view holds that the –\textit{s} plural dislike is grammatical in nature, reflecting a morphological constraint against regular inflection feeding lexical compounding. An alternative account is offered by Ramscar and Dye (2010) who argued that the interpretation patterns in noun compounds (as well as other domains of language) reflect conventions directly learned from the input. Specifically, children (and adults) are claimed to disprefer regular plurals (as well as irregular ones) inside compounds because they do not hear them in the input. According to this proposal, we would expect to find parallel developments for compounds with regular and irregular plural non-heads as opposed to those with singular non-heads, due to children ‘learn[ing] conventions that ordinarily exclude both regular and irregular plurals from compounds’ (Ramscar & Dye, 2010: 36). Note, however, that our results from both children’s as well as adult’s looking-while-listening behavior demonstrate contrasts between regular and irregular plurals inside compounds. It is hard to see how this finding could be explained in terms of Ramscar and Dye’s (2010) learning account. Furthermore, Ramscar and Dye (2010) argued that the preference for the recursive interpretation of compounds with regular plural
non-heads is an artifact of the types of visual stimuli presented in previous experiments. Consider, for example the kinds of visual stimuli presented to participants in Alegre and Gordon’s (1996) study. They would see, for example, an image of a red monster eating green rats, alongside an image of a green monster eating red rats. Upon hearing *red* in the auditory stimulus listeners have a choice of deciding either the monster or the rats to be red. Once they hear *rats* their attention is directed to the image of the red rats, as hearing this new information helps to disambiguate the interpretation. On the other hand, hearing *rat* does not bias participants towards any of the two pictures, as neither image contains a single rat. Hence, according to Ramscar and Dye (2010) the combination of incremental processing together with the plural-bias types of visual stimuli may have caused an apparent preference for recursive compound interpretations in the regular plural condition. Could this also explain the current online results? It is true that Ramscar and Dye’s point applies to studies that directly compare compounds with plural to those with singular non-heads, as was the case in Alegre and Gordon (1996). Note, however, that our critical comparison for assessing the role of the morphological constraint was between compounds with regular and those with irregular plural non-heads. According to Ramscar and Dye’s idea, participants should look towards the picture depicting the recursive interpretation upon hearing the plural noun irrespective of whether the plural form is regular or irregular. This, however, was not the case. Instead, the results yielded a significant preference for the recursive interpretation of compounds with regular (compared to irregular) plural non-heads for both adults and children. We conclude that Ramscar and Dye’s (2010) account fails to explain the current set of data.
6.2 *The timecourse of the compounding constraints*

There is one previous study that examined the plurals-in-compounds effect in real-time language comprehension, Cunnings and Clahsen’s (2007) eye-movement-during-reading study with adults. They found that early first-pass reading time measures (first-fixation and gaze durations) yielded longer reading times for compounds with regular plural non-heads compared to those with both irregular plural and singular non-heads. By contrast, later second-pass reading time measures yielded longer reading times for compounds with plural non-heads (both regular and irregular ones) compared to those with singular ones. Cunnings and Clahsen (2007) concluded from these findings that the morphological constraint applies earlier during processing than the semantic constraint. The results from the current looking-while-listening experiment are consistent with those of Cunnings and Clahsen’s (2007) reading study. As illustrated in Figures 2A and 2B, the data from the adult group suggest that eye-gaze changes attributable to the morphological constraint occurred before those resulting from the semantic constraint. Figure 2A shows that compounds with regular plural non-heads yielded an increased number of looks towards images with a recursive interpretation between 200ms and 500ms, i.e. considerably earlier than the corresponding gaze change between 700ms and 1,000ms for head nouns of compounds with plural (compared to singular) non-heads (Figure 2B). In the child data, a similar contrast in timing was found; see Figures 4 and 5. These results suggest that both spoken and written language processing are affected by the compounding constraints, which unfold over time in a similar manner.
6.3 Developmental issues

The present results reveal a number of differences between younger children on the one hand, and adults as well as older children on the other hand. Firstly, whilst children’s eye-gaze patterns were parallel to those of adults in that violations of the –s plural constraint elicited changes of looks towards the picture depicting the recursive compound interpretation, the younger children showed this preference for a later time window than the older children; see Figure 4. Secondly, whilst adults’ and older children’s eye-gaze patterns were similar in that compounds with plural non-heads (relative to singular ones) elicited a higher proportion of recursive compound interpretations than those with singular non-heads, this preference was not found for the younger children; see Figure 5. These results suggest that children are sensitive to the morphological constraint across the age range tested, whereas sensitivity to the semantic constraint emerges later, between nine and ten years of age.

The current findings on children’s performance on plurals inside compounds are consistent with previous reports from online studies of children’s morphological and syntactic processing indicating developmental changes of processing amongst school-age children with respect to the speed of processing and their reliance on structural versus non-structural cues to interpretation. Slower processing in younger than older children (and adults) was found in a number of studies for both morphological and sentence-level phenomena (e.g. Felser et al., 2003; Clahsen, Hadler & Weyerts, 2004). Consider, for example, Clahsen, Lueck & Hahne’s (2007) event-related potentials study in which six-to-twelve-year-old children (and an adult control group) listened to correctly and incorrectly inflected German noun plural forms presented in sentence contexts while EEGs were recorded from their brains. Whilst children and adults demonstrated similar brain potentials, the younger children’s responses had
later onsets than the older ones and the adult group. These and other related findings from EEG studies (e.g. Hahne, Eckstein & Friederici, 2004; Silva-Pereya, Riveira-Gaxiola & Kuhl 2005) suggest that language processing in school-age children may be less efficient than in adults.

We also found that whilst older children’s and adults’ eye-gaze patterns were affected by both constraints, the younger children’s performance indicated sensitivity to the morphological, but not the semantic constraint. This contrast is reminiscent of results from sentence-processing studies showing that children are less capable of rapidly integrating structural and non-structural information during online processing than adults (e.g. Trueswell, Sekerina, Hill & Logrip, 1999; Traxler, 2002; Hurewitz, Brown-Schmidt, Thorpe, Gleitman & Trueswell, 2001; Weighall 2008). Consider, for example, Traxler (2002) who studied eight-to-twelve-year-old children's processing of sentences containing temporary subject-object ambiguities using self-paced reading. He found that in sentences such as When Sue tripped the girl/the table fell over…, the children tended to analyze the post-verbal NP as a direct object regardless of whether or not this analysis was semantically plausible. According to Traxler (2002), these results show that children make use of structurally based parsing principles for online ambiguity resolution (which in the above example would favor a direct object interpretation) in the same way as adults, but that (unlike adults) they even do so if this analysis is semantically inappropriate. Evidence indicating that children focus more on structural or bottom-up information during processing than adults can also be found from studies of children’s processing of anaphoric expressions; see Felser and Clahsen (2009) for review. How to account for these child/adult differences is, however, not yet clear. They are unlikely to reflect children’s insensitivity to semantic and pragmatic information per se, as several studies have shown that young children
are indeed sensitive to verb semantics (e.g. Kidd & Bavin, 2007) and also to
discourse-level information (Song & Fisher, 2007) during processing. One possibility
is capacity limitations. Assuming that the integration of different information sources
incurs additional processing costs, children’s relatively greater difficulty in this
domain may simply be due to a less efficient processing system than that of adults.
Another possibility is that non-linguistic mechanisms that are relevant for rapidly
integrating different sources of information during processing, e.g. executive function
and cognitive control mechanisms, are still developing during late childhood (e.g.
Novick, Trueswell, & Thompson-Schill, 2010). Further research is required to better understand the sources of these developmental changes.

7. Conclusion
This study examined the online processing of plurals in compounds by testing adults
and children in a visual world experiment. The adults and children showed evidence
of compound processing being governed by a morphological constraint against
regular plural but not irregular plural non-heads. Furthermore, the adults and older
children showed that performance on compounds is also affected, albeit at a later
stage of processing, by a semantic constraint which prefers singular non-heads inside
compounds. We conclude that it takes time for children’s processing of compounds to
become adult-like.
ACKNOWLEDGMENTS

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